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OXYGEN AND CARBON DIOXIDE LEVELS FOR CONTROLLED-ATMOSPHERE STORAGE OF STARKING AND GOLDEN DELICIOUS APPLES

U.S. DEPARTMENT OF AGRICULTURE, AGRICULTURAL MARKETING SERVICE, MARKET QUALITY RESEARCH DIVISION

CONTENTS

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SUMMARY

There were no appreciable differences in flesh firmness, soluble solids, and taste panel ratings of Starking Delicious and Golden Delicious apples from regular storage and controlled-atmosphere storage with oxygen levels of 5, 3, and 1.7 percent and less than 1 percent carbon dioxide. All fruit from controlled-atmosphere storage had higher total acidity than fruit from regular storage. The taste panel generally expressed a slight preference for the controlled-atmosphere fruit.

In an atmosphere of 9.5 percent carbon dioxide and 11.0 percent oxygen, the high carbon dioxide caused softening and breakdown of the fruit.

There were no marked differences in fruit from atmospheres in which the oxygen had been reduced to 5 percent in 10, 20, or 40 days.

Monoethanolamine was a satisfactory scrubbing agent for the removal of CO_2 from the storage air.

OXYGEN AND CARBON DIOXIDE LEVELS FOR CONTROLLED-ATMOSPHERE STORAGE OF STARKING AND GOLDEN DELICIOUS APPLES

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INTRODUCTION

Background

Since the marketing season for Washington State Delicious apples extends over 9 to 10 months, the fruit must be stored under the best conditions possible to be of good quality when it reaches the consumer. Controlled-atmosphere (CA) storage has been used in England for many years and is being rather widely adopted in the United States. Initially, CA storages were used for varieties of apples which cannot be stored for long periods at 31° F. without developing disorders. Smock [1] reported that McIntosh, which in regular storage at 32° F. develops brown core, was essentially free from brown core and had an extended shelf life when held in CA storage at 38°. He also reported some benefit to Delicious from CA storage. Schomer and Sainsbury [2] found that Starking Delicious grown in the Pacific Northwest and stored in 3.2 and 4.4 percent oxygen were superior in appearance and texture to similar fruit held at 6.2 percent oxygen or in regular storage.

The first commercial CA storage in Washington was in 1957 and utilized a plastic tent inside a regular cold storage room. This was followed by the construction of permanent CA storages.

The apple-growing States with CA storages have passed laws which require CA storage operators to meet certain minimum requirements before they may use the CA label. These laws generally follow the pattern established in New York, which was the first State to regulate CA storage procedures. The Washington State law, which was adopted in 1961, requires that oxygen be reduced to 5 percent within 20 days after the room is sealed, that fruit be held for at least 90 days in CA storage, and that the apples meet U.S. condition standards for export upon removal to be labeled CA fruit. During the rapid expansion of CA storages in the Pacific Northwest, the general recommendations of 2.5 to 3 percent oxygen and 1 to 3 percent carbon dioxide have been used.

Objectives

The following experiments were conducted with Starking Delicious and Golden Delicious apples to determine the optimum oxygen and carbon dioxide levels, the effect of the length of time to reach 5 percent oxygen after the room is sealed, and the effectiveness of monoethanolamine as a carbon dioxide scrubbing solution. This study was part of a broad program of research to reduce deterioration and to prolong the life of fresh produce moving through marketing channels.

[1] Smock, R. M. Controlled Atmosphere Storage of Apples. Cornell Univ. Agr. Exp. Sta. Bul. 759. 1958.

[2] Schomer, H. A., and Sainsbury, G. F. Controlled Atmosphere Storage of Starking Delicious Apples in the Pacific Northwest. U. S. Dept. Agr., AMS–178. 1957.

OXYGEN LEVEL IN CONTROLLED-ATMOSPHERE STORAGE

Oxygen concentration of 2.5 to 3 percent has been recommended for CA storage of Delicious. A test was conducted to determine the possible advantages of a lower oxygen level and also the effect of a high carbon dioxide concentration with an oxygen concentration of 11 percent.

Methods

Apples harvested about 148 days from full bloom (65 percent of blossoms open on north side of tree) were randomized and placed in CA rooms and cabinets, and in a regular cold storage room. Two small rooms of 175-box capacity were used; one room was maintained at approximately 1.5 percent oxygen and the other at 3.0 percent, and both at less than 1 percent carbon dioxide. The atmosphere in a cabinet previously used experimentally for CA studies [3] was allowed to balance at about 11 percent oxygen and 10 percent carbon dioxide by respiration of the fruit. This condition was maintained by ventilation. Check fruit was held in a regular cold storage room. The four storage conditions used are listed in table 1.

Thermocouples were placed in fruit and in the air in selected locations so that comparable fruit temperatures could be maintained. The required oxygen level was reached in the appropriate time by flushing the rooms with nitrogen. Carbon dioxide was removed by continually scrubbing the room air.

Fruit from the three rooms were sampled and evaluated in April, and fruit from all four storage conditions were evaluated in June at the end of the test. Quality measurements were made on samples of 20 apples each. Firmness was determined with a Magness-Taylor pressure tester, soluble solids with a Zeiss hand refractometer, pH with the glass electrode, total acids by titration to pH 7.0, and organoleptic analyses by a five-member taste panel.

Results

The average temperatures and percentages of oxygen and carbon dioxide maintained during the storage period are shown in table 1.

Starking Delicious

Examination upon removal from cold storage indicated that fruit from the CA (1.7 or 3.0 percent O_2) and regular storage (check) rooms had about the same degree of firmness (table 2). Apples stored in 11.1 percent oxygen and 9.5 percent carbon dioxide were 0.5 to 1.0 pound softer than the check fruit. When the fruit was placed at 70° F., that from CA storage softened faster than that from regular storage. After 7 days at 70° F., all lots of CA apples had lost approximately 2 pounds in firmness while the check fruit had lost only about 1 pound.

The loss of acid from apples in CA storage was consistently less than from comparable fruit in regular storage. Acid loss was similar in the fruit from 1.7 and 3.0 percent oxygen. The acid reduction was as follows: After 6 months' storage—check, 50 percent, and CA, 20 percent; after 8 months' storage—check, 60 percent, and CA, 35 percent. The apples stored in 9.5 percent carbon dioxide lost only 20 percent after 8 months' storage.

There was a slight indication of higher soluble solids in the CA fruit but the differences were too small to be significant.

The type of storage did not have a significant effect on the taste panel ratings. Fruit after 6 months' storage was rated somewhat higher than fruit after 8 months' storage. As expected, fruit held at 70° F. for 4 or 7 days was rated lower than fruit taken directly from cold storage.

Golden Delicious

Fruit from the 3.0 and 1.7 percent oxygen rooms was slightly firmer than fruit in the check lot at the time of removal from storage (table 3). After 4 and 7 days at 70° F., this difference had about disappeared. The fruit from 11.1 percent oxygen and 9.5 percent carbon dioxide, softened rapidly at 70° and had breakdown after 7 days at this temperature.

The acid level in Golden Delicious at harvest was almost twice as high as that in Starkings. However, the percentage loss in storage was greater in Golden Delicious. The percentage reduction of acid in the fruit after 8 months in the different storages was as follows: 9.5

[3] See footnote 2.

percent carbon dioxide, 45 percent; 3 percent oxygen, 60 percent; 1.7 percent oxygen, 55 percent; and regular storage, 75 percent.

Soluble solids generally were slightly higher in the CA fruit. In the taste evaluations, the CA fruit from the 3.0 and 1.7 percent oxygen rooms were rated higher than the fruit from regular storage. Fruit from the high carbon dioxide cabinet was of poor quality upon removal and broke down rapidly.

TABLE 1.—*Oxygen and carbon dioxide concentrations and temperatures in controlled-atmosphere storages and temperatures in regular storage, for Starking and Golden Delicious Apples*

Storage	Proposed concentration		Average concentration for storage season		Average fruit temperature during storage
	Oxygen	Carbon dioxide	Oxygen	Carbon dioxide	
	Percent	*Percent*	*Percent*	*Percent*	*°F.*
CA Room 1	3.0	1	3.0	0.6	31.7
CA Room 2	1.5	1	1.7	0.5	30.6
CA Cabinet	11.0	10.0	11.1	9.5	33.1
Regular storage	(Normal atmosphere about 21.0 percent oxygen and 0 carbon dioxide)				31.3

TABLE 2.—*Quality evaluation of Starking Delicious apples from controlled-atmosphere storage with different levels of oxygen and carbon dioxide*

Length and type of storage, and time of evaluation	Firmness	Soluble solids	pH	Total acidity (malic)	Panel rating
	Pounds	*Percent*		*Percent*	
No storage (at harvest)	15.0	12.7	3.93	0.225	
180 days at 31° F.:					
CA room 1, 3.0% O_2:					
At removal from storage	12.1	13.6	4.19	.174	81
Plus 4 days at 70°	9.5	13.3	4.32	.149	70
Plus 7 days at 70°	9.3	13.5	4.30	.140	73
CA room 2, 1.7% O_2:					
At removal from storage	11.7	13.9	4.18	.180	81
Plus 4 days at 70°	9.7	13.4	4.31	.143	77
Plus 7 days at 70°	9.9	14.0	4.28	.149	72
Regular storage (check):					
At removal from storage	11.7	13.4	4.44	.117	79
Plus 4 days at 70°	11.4	13.0	4.50	.118	78
Plus 7 days at 70°	10.6	13.5	4.48	.101	70
240 days at 31° F.:					
CA room 1, 3.0% O_2:					
At removal from storage	11.3	13.4	4.21	.157	71
Plus 4 days at 70°	10.6	13.0	4.33	.140	70
Plus 7 days at 70°	9.0	13.3	4.34	.134	65
CA room 2, 1.7% O_2:					
At removal from storage	11.1	13.5	4.28	.142	72
Plus 4 days at 70°	10.2	13.0	4.37	.138	70
Plus 7 days at 70°	9.2	13.1	4.41	.113	64
CA cabinet, 11.1% O_2, 9.5% CO_2:					
At removal from storage	10.6	13.5	4.14	.175	71
Plus 4 days at 70°	9.9	12.7	4.23	.161	70
Plus 7 days at 70°	8.7	14.0	4.38	.137	66
Regular storage (check):					
At removal from storage	11.8	13.1	4.56	.095	72
Plus 4 days at 70°	10.9	13.1	4.68	.086	67
Plus 7 days at 70°	10.9	13.1	4.74	.080	68

TABLE 3.—*Quality evaluation of Golden Delicious apples from controlled-atmosphere storage with different levels of oxygen and carbon dioxide*

Length and type of storage, and time of evaluation	Firmness	Soluble solids	pH	Total acidity (malic)	Panel rating
	Pounds	*Percent*		*Percent*	
No storage (at harvest)	16.1	14.6	3.56	0.426	
180 days at 31° F.:					
CA room 1, 3.0% O_2:					
At removal from storage	10.5	14.3	4.09	.202	77
Plus 4 days at 70°	9.9	14.6	4.20	.181	76
Plus 7 days at 70°	10.2	14.8	4.14	.182	76
CA room 2, 1.7% O_2:					
At removal from storage	10.7	14.5	4.01	.225	79
Plus 4 days at 70°	10.2	14.6	4.16	.201	78
Plus 7 days at 70°	10.2	14.8	4.15	.186	74
Regular storage (check):					
At removal from storage	10.2	14.1	4.32	.153	73
Plus 4 days at 70°	10.0	14.3	4.44	.126	73
Plus 7 days at 70°	9.7	14.1	4.32	.154	72
240 days at 31° F.:					
CA room 1, 3.0% O_2:					
At removal from storage	11.0	14.3	4.19	.176	73
Plus 4 days at 70°	10.0	13.2	4.28	.146	74
Plus 7 days at 70°	8.9	13.3	4.37	.134	74
CA room 2, 1.7% O_2:					
At removal from storage	10.8	14.0	4.16	.193	74
Plus 4 days at 70°	10.0	13.1	4.24	.157	74
Plus 7 days at 70°	9.8	13.6	4.36	.137	73
CA cabinet, 11.1% O_2, 9.5% CO_2:					
At removal from storage	10.1	13.9	4.02	.234	68
Plus 4 days at 70°	8.3	13.7	3.98	.236	59
Regular storage (check):					
At removal from storage	10.1	13.5	4.55	.109	69
Plus 4 days at 70°	9.6	13.9	4.52	.117	71
Plus 7 days at 70°	9.2	14.0	4.58	.096	70

OXYGEN PULL-DOWN PERIOD

Twenty days may be sufficient to lower the oxygen to 5 percent through respiration of the fruit if the storage temperature is held at 38° to 40° F. as is done with McIntosh and other cold-sensitive varieties. This was the type of CA storage when the New York law was written. However, at 30° to 31°, Delicious apples have not reduced the oxygen to the required 5-percent level in 20 days in commercial CA rooms, with the result that gaseous nitrogen must be added to the room to bring the oxygen down to the required level in time. This adds considerable expense to CA storage operation.

Since the 20-day interval was based on McIntosh apples at 38° to 40° F., it seems reasonable that a longer period might be allowed for Delicious apples at 31° without adversely affecting the fruit. Oxygen pull-down periods of 10, 20, and 40 days were tested to determine if these intervals of oxygen reduction time would have a measurable effect on the storage life of the apples.

Methods

Two CA storage rooms were filled with commercially packed fruit and 10 boxes of test fruit which were from a uniform, randomized lot. The oxygen in these rooms was reduced to 5 percent in 20 days in accordance with regular practice. Oxygen was maintained at 5 percent in one of the rooms, while in the other room it was further reduced by respiration of the fruit until it reached 3 percent. These oxygen levels were maintained for the entire storage season. Twenty boxes of test fruit were also placed in each of 2 airtight cabinets. The reduction of oxygen to 5 percent was regulated by the introduction of nitrogen and air so that the pull-down periods were 10 days for one cabinet and 40 days for the other. On the 40th day, 10 boxes of fruit from each cabinet

were placed in each of the CA rooms where they remained for the rest of the storage season. The carbon dioxide in both rooms was held at 1 percent or less by continuous air scrubbing.

Fruit was removed after 90 days storage, the period necessary to qualify for CA stored Delicious, and at 210 days, at which time the tests were terminated. Fruit was evaluated for quality upon removal from 31° F. storage and after 4 days at 70°. Evaluation of quality upon removal from 31° storage was made within a week after removal from the controlled atmosphere

Results

No consistent differences were detected at the end of a storage season in lots of apples from CA storages in which the oxygen had been lowered to the 5-percent level in 10, 20, and 40 days (table 4).

Firmness, soluble solids, and acidity

No marked or consistent differences in flesh firmness were found between the 10-, 20-, and 40-day fruit upon removal from storage, either after 90 days or after 7 months. With an additional 4 days at 70° F. the 40-day fruit generally softened slightly more than the 10- and 20-day lots. The check fruit from regular storage generally tested about 1 pound softer than the average for the CA fruit. However, the fruit temperature in the regular storage averaged about 1 degree higher than in the CA storage. There were no appreciable differences in soluble solids between any of the lots. Acidity of the fruit from CA rooms remained higher than that of the fruit from regular storage. Acidity is the one objective measurement that consistently separates the CA stored fruit from regular stored fruit. However, the acidity did not show any consistent trend among the 10-, 20-, and 40-day lots.

Taste panel ratings

No consistent preference was shown by the taste panel for any one of the 10-, 20-, or 40-day lots. The numerical ratings generally indicated good quality, and the average ratings were fairly uniform. After 7 months' storage, apples from regular storage and from the room with 5 percent oxygen were rated slightly inferior to those from the room with 3 percent oxygen.

TABLE 4.—*Quality evaluation of Starking Delicious apples from controlled-atmosphere storage for which 10-, 20- and 40-day periods were used for oxygen reduction to the 5 percent level*

Length and type[1] of storage	Evaluation upon removal from storage					Evaluation after holding for 4 days at 70° F.				
	Firmness	Soluble solids	pH	Total acidity (malic)	Panel rating	Firmness	Soluble solids	pH	Total acidity (malic)	Panel rating
	Pounds	*Percent*		*Percent*		*Pounds*	*Percent*		*Percent*	
No storage (at harvest)	17.9	11.6	3.88	0.246						
90 days at 31°:										
CA Room 1, 5% O_2										
10-day lot	16.2	13.6	4.00	.246	88	15.3	13.1	4.09	0.206	83
20-day lot	16.1	13.0	4.00	.236	89	16.1	13.2	4.06	.214	84
40-day lot	16.7	13.0	4.00	.236	85	15.4	13.4	4.01	.228	86
CA Room 2, 3.0% O_2										
10-day lot	17.0	13.2	4.00	.222	87	16.3	13.0	4.01	.217	85
20-day lot	16.7	13.6	3.97	.244	82	16.3	13.8	4.02	.228	83
40-day lot	16.7	12.9	3.98	.241	85	15.5	13.1	4.01	.222	82
Regular storage (check)	16.1	13.3	4.08	.212	84	15.1	13.4	4.18	.209	83
210 days at 31°:										
CA Room 1, 5% O_2										
10-day lot	15.7	13.1	4.10	.200	74	14.4	13.3	4.09	.177	83
20-day lot	15.3	13.0	4.22	.193	76	15.1	12.7	4.00	.192	77
40-day lot	14.4	13.0	4.18	.193	83	13.4	13.4	4.24	.162	81
CA Room 2, 3.0% O_2										
10-day lot	15.4	13.0	4.12	.209	84	15.4	13.2	4.13	.177	82
20-day lot	14.7	13.5	4.12	.217	85	14.8	12.7	4.10	.201	84
40-day lot	15.2	13.0	4.12	.206	82	14.6	12.8	4.10	.177	82
Regular storage (check)	14.2	13.2	4.32	.163	80	13.6	12.8	4.25	.123	79

[1] Average fruit temperature for storage season: CA Room 1, 30.9° F.; CA Room 2, 30.6°; Regular Storage, 31.6°. Carbon dioxide concentration maintained at less than 1% in all storage rooms.

For conventional CA storages maintaining carbon dioxide at 1 percent or less, a dilute solution of caustic soda (sodium hydroxide) is generally used to remove the carbon dioxide liberated by the fruit during respiration. The atmosphere from the CA room is pumped through air scrubbers containing a 1- to 3-percent solution of sodium hydroxide. Generally, the caustic solution needs to be changed two or three times daily during the pull-down period. When the desired level has been established, the solution needs to be changed once every day or two. This is a tedious task, the caustic must be handled with care, and it presents a disposal problem.

Alkanolamines have been widely used as CO_2 absorbents, and in these studies one of them, monoethanolamine, was used as the scrubbing agent. The organic base reacts with carbon dioxide gas, forming a salt, from which the carbon dioxide may be liberated with heat and the amine regenerated.

Monoethanolamine solidifies at approximately 50° F. However, a 30-percent solution in water does not freeze until the temperature reaches about 5° F. All work reported here was done with a 30-percent solution of monoethanolamine.

TABLE 5.—*Volume of carbon dioxide absorbed by 2 ml. of 30-percent solutions of fresh and used monoethanolamine (MEA) in specified intervals*

(In milliliters)

Absorption interval	New MEA	Used MEA from CA	Reactivated MEA (24 hr.)
5 minutes	124	6	112
5 to 10 minutes	15	7	14
10 to 15 minutes	12	3	5
Total, 15 minutes	151	16	131

Methods

The capacity of the monoethanolamine to take up carbon dioxide was determined by measuring the volume of CO_2 gas absorbed by 2-ml. samples of the 30-percent solution (table 5). Reactivation was accomplished by refluxing in a 12 liter round-bottom flask set in a heating mantle. A variac was used to regulate the intensity of boiling.

Results

The 2 ml. of new monoethanolamine absorbed 151 ml. of carbon dioxide in 15 minutes. After the monoethanolamine had been used for scrubbing the atmosphere from CA storage until the CO_2 reached 1 percent, its remaining CO_2 absorptive capacity was only about 10 percent of the original capacity.

The absorptive capacity of monoethanolamine after several intervals during reactivation of a 2.5-gallon batch is given in table 6.

Monoethanolamine proved to be more satisfactory than sodium hydroxide for a CO_2 scrubbing agent. It was easier to handle, did not need changing as often, was more effective in reducing the CO_2 level, and could be reactivated by heating. The same solutions were used repeatedly for 5 storage seasons with little loss in effectiveness. Five gallons of 30 percent monoethanolamine were used in the scrubbing chamber for each 175-box room. This was sufficient to lower the carbon dioxide from 1.0 to 0.3 percent in 48 hours and to keep the carbon dioxide concentration below 1.0 percent for 10 to 14 days. The air from the storage room was passed through activated carbon to remove the volatiles before it entered the scrubber, and the return air was passed through carbon to prevent any monoethanolamine from being carried into the CA storage.

TABLE 6.—*Volume of carbon dioxide absorbed by 2 ml. of 30-percent solutions of used and reactivated monoethanolamine (MEA) in specified intervals, by length of refluxing time*

(In milliliters)

Absorption interval	Used MEA	Refluxing time					
		1 hr.	2 hr.	4 hr.	8 hr.	24 hr.	48 hr.
5 minutes	11	38	58	62	75	106	129
5 to 10 minutes	5	9	12	11	12	12	14
10 to 15 minutes	1	4	5	6	4	5	6
Total, 15 minutes	17	51	75	79	91	123	149

DISCUSSION AND CONCLUSIONS

Delicious apples from CA storage in Washington must meet export standards to qualify for the CA label. This requires fruit at least in the firm-ripe condition. Apples of this condition would usually have a minimum pressure test reading of 11 pounds on the Magness-Taylor pressure tester. Flesh firmness of apples at desirable picking maturity varies from year to year and from area to area. With Delicious, only hard fruit (above 16.5 pounds pressure) should be considered for long storage.

In the first test described in the section on "Oxygen Level in CA Storage" (tables 2 and 3), firmness of the apples at harvest averaged 15 pounds, which was below the desired firmness for long storage. The growing season had not been favorable and fruit at proper maturity was softer than usual. During storage there was no consistent difference in the rates of softening of Starking Delicious from rooms with 3 percent and 1.7 percent oxygen or from regular storage held under the same conditions of temperature and humidity. Golden Delicious apples from regular storage were generally slightly softer than the CA fruit.

Early work in England indicated a definite benefit from levels of 5 to 10 percent carbon dioxide in gas storages for a number of their apple varieties.[4] Golden Delicious regularly are held at 9 percent carbon dioxide and 11 percent oxygen in Holland,[5] but at 38° F. rather than the 30°-32° F. recommended in the United States. Fisher[6] reported that CO_2 levels of 5 percent and above increased the rate of softening and mealiness of Delicious. In the test reported here, both Starking and Golden Delicious stored in the cabinet with 9.5 percent CO_2 at 31° softened rapidly when placed at 70° F. After 7 days at 70° F., all of the Golden Delicious from the cabinet had breakdown which undoubtedly was a result of the high carbon dioxide level during the cold storage period.

In the second test, the Starking Delicious from CA storage were a little firmer than the check fruit (table 4). However, as noted previously, the average fruit temperature in the regular storage was approximately 1 degree higher than the CA fruit, which would account for at least part of the lower firmness in the check apples. Variations in firmness occurred among fruits in the same treatments at different sampling dates, and therefore firmness was not a consistent indicator of the treatment received. Fruit from one room might be firmer than that from the other rooms at one examination, but not at another. Starking Delicious apples from CA softened more rapidly at 70° than those from regular storage in one test (table 2), but did not in another (table 4). In general, the small differences found in the rates of ripening of the fruit from all the storages were not sufficiently consistent to justify the conclusion that one storage condition was significantly superior to another.

Apples from CA storage are consistently more acid than those from regular storage.[7] Furthermore, acid level in the fruit was proportional to the carbon dioxide level in the atmosphere. The higher acid level in apples from CA sometimes imparts a tartness to the flavor which may give tasters the impression that CA apples are "tree fresh." Some individuals, however, do not appreciate the acid flavor but prefer the sweeter, more bland taste of fruits with low acid. The taste panel ratings indicated little preference among tasters between fruit from the two CA rooms and regular storage fruits.

In controlled-atmosphere storage, 3 percent oxygen was slightly superior to 5 percent for Starking Delicious as indicated by the panel ratings after 210 days' storage (table 4). There were no marked differences in fruits from atmospheres in which the oxygen had been reduced to 5 percent in 10, 20, or 40 days. The results indicate that the 20-day period allowed by Washington State law for lowering the oxygen level to 5 percent could be lengthened to 30 days, which would allow the required oxygen level to be reached through respiration of the fruit in a well-constructed CA room. This would obviate the expense of introducing nitrogen to lower the oxygen level. The 30-day period which is allowed in Michigan could be allowed in Washington without sacrificing quality of the fruit.

[4] Kidd, F. and West, C. The Refrigerated Gas Storage of Apples. Dept. Sci. and Indus. Res. Food Investigation Board (Great Britain), Leaflet No. 6, (Revised 1950).

[5] Samenstelling en uitgave van de Directie van de Tuinbouw, Ministerie van Landbouw en Visserij, p. 406, Tuinbouwgids, 1960.

[6] Fisher, D. V. Storage of Delicious Apples in Artificial Atmospheres. Amer. Soc. Hort. Sci. Proc. 37: 459-462, 1939.

Fisher, D. V. Mealiness and Quality of Delicious Apples as Affected by Growing Conditions, Maturity and Storage Techniques. Sci. Agr., 23:10. June 1943.

[7] See footnote 2.

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